INFRARED IMAGING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

In general, the present invention relates to an
infrared imaging apparatus and, more particularly,
relates to correction of shading included in data of a
picture taken by infrared imaging apparatus.

Description of the Related Art

Each substance radiates substance-temperature-
dependent electromagnetic waves caused by motions of
atoms or molecules on the surface of the substance unless
the temperature of the substance is equal to the absolute
zero. The maximum wavelength of electromagnetic waves
radiated by many substances on the earth has a value in
an infrared range. An infrared imaging apparatus is an
apparatus for carrying out image processing by detection
of infrared rays. In many cases, an infrared imaging
apparatus is used in light reception equipment. One of
most outstanding features of an infrared imaging
apparatus is a characteristic that allows such equipment
to be designed into small and light one. In general, such
light-receiving equipment is referred to as a passive
system. On the other hand, a system comprising a set of a

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transmission apparatus and a reception apparatus is known

as an active system. Since an infrared passive system

does not radiate an electromagnetic wave by using a

transmission apparatus as a radar does, such a system has

a characteristic of high concealability. For this reason,

such a system has been developed for military purposes

and has become the base of development of infrared

technologies. At the present time, a number of

application products centered at an image processing

apparatus are available in the market as consumer

products. The reception apparatus of the infrared system

comprises a camera head for detecting infrared rays and

converting the infrared rays into electrical signals, an

A/D converter for converting an analog signal into

digital data and an image-processing unit for processing

the digital data representing an image in accordance with

an application.

FIG. 32 is a diagram showing the general

configuration of the camera head. As shown in the figure,

the camera head 2 comprises an optical system 4 and an

infrared detector 6. The optical system 4 comprises a

lens 8 and a lens housing 10. The lens 8 condenses

infrared rays. The lens housing 10 plays roles of

supporting the lens 8 and preventing reflection of

infrared rays by absorption of the infrared rays introduced to the inside of the lens housing 10. Such reflection is a cause of noise. The infrared detector 6 comprises a window 12, a cold shield 14, an infrared sensor 16, an inner shell 18 and an outer shell 20. The window 12 is a window for passing through infrared rays. The cold shield 14 plays a role of reducing the quantity of an unnecessary infrared ray hitting the infrared sensor 16. The infrared sensor 16 plays a role of outputting electrical signals with a level proportional to the intensity of incident infrared energy. The inner shell 18 and the outer shell 20 play a role of accommodating the infrared sensor 16.

FIG. 33 is a diagram showing a typical configuration of the camera head 2. The lens 8 shown in the figure comprises a plurality of lenses 8a to 8d. The lens 8a is made of Si while the lens 8b is made of ZnSe. On the other hand, the lens 8c is made of Ge while the lens 8d is made of Si. The window 12 is made of Ge and the cold shield 14 is a metallic plate. The infrared sensor 16 is made of semiconductor such as $Hg_{1-x}Cd_x$, Te or $Pb_{1-x}Sn_xTe$. The inner shell 18 and the outer shell 20 are each made of a metal such as kovar.

FIG. 34 is a diagram showing a typical

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implementation of the infrared detector 6 shown in FIG.
32. The infrared detector 6 is a vacuum thermal-
insulating container having a dual structure comprising
the inner shell 18 and the outer shell 20. On a portion
of the outer shell 20, the window 12 is provided. On the
inner shell 18 facing the window 12, the infrared sensor
16 is mounted. The inner shell 18 of the vacuum thermal-
insulating container accommodates refrigerant such as
liquid nitrogen. As an alternative, a cryostat 28
adopting a Joule-Thompson law operates at a predetermined
temperature. The cold shield 14 is provided so as to
enclose the infrared sensor 16. The cold shield 14
reduces the quantity of an unnecessary infrared ray
entering the infrared sensor 16. Electrodes of the
infrared sensor 16 and their conductor patterns are
connected to each other by bonding wires 22 adopting a
bonding technique. Infrared rays detected by the infrared
sensor 16 is output to an external device as analog
electrical signals appearing on lead pins 26 which are
connected to semiconductor patterns by bonding wires 24.
The analog electrical signals output from the lead pins
26 are each converted by the AD converter into digital
data consisting of a predetermined number of bits. The
digital data is supplied to the image-processing unit

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such as an apparatus for keeping track of an observation

target or implementing medical treatment. In the image-

processing unit, the digital data is subjected to various

kinds of image processing.

FIG. 35 is an explanatory diagram used for

describing a role played by the cold shield 14. As

described above, the cold shield 14 is provided so as to

enclose the infrared sensor 16. The inner surface of the

cold shield 14 is coated with a black coating material.

Baffles 30 are provided on the walls of the inner surface.

The baffles 30 each reduce the quantity of an unnecessary

infrared ray entering the infrared sensor 16. The cold

shield 14 is designed so that infrared rays in a range

denoted by reference numeral 32 are condensed by the lens

8 at a position A on the surface of the infrared sensor

16. In general, about a photographed picture output by

the camera head 2 infrared rays are incident on the

surface of the infrared sensor 16 not in a uniform

irradiance distribution even if the picture is taken as a

result of photographing a scene or an image-taking object

having a uniform distribution of radiation intensities.

Instead, a signal output by the infrared sensor 16 shows

a quadratic-function distribution with respect to the

position of a field of view. This quadratic-function

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distribution is a phenomenon known as shading. If the shading phenomenon becomes too excessive, an accurate picture of the scene or the objects of image-taking cannot be taken, and the objective of the image-taking cannot be achieved in some cases. In order to reproduce accurate picture information of a scene or another image-taking object by using an image-taking unit, it is necessary to adopt a shading correction method capable of effectively removing only shading components from a signal generated by the infrared sensor 16.

FIG. 36 is an explanatory diagram used for describing the aforementioned shading phenomenon. The shading phenomenon occurring in an infrared imaging apparatus includes two components, namely, a shading component caused by an optical system and a shading component caused by a housing comprising the lens housing 10, the inner shell 18 and the outer shell 20. The shading component caused by the optical system is a shading component due to irradiance distribution which is developed on the surface of the infrared sensor 16 when an image is created by scene components 40 passing through an effective aperture of the optical system. On the other hand, the shading component caused by the housing parts containing the lens housing 10, the inner

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shell 18 and the outer shell 20 is a housing components 42 incident to the infrared sensor 16. The infrared rays are radiated by the lens housing 10, the inner shell 18 and the outer shell 20 themselves, which constitute the housing as described above. The shading component caused by the housing parts is peculiar to an infrared imaging apparatus and does not exist in a visible image-taking apparatus. The most important problem raised in the shading correction method adopted by the infrared imaging apparatus is how to effectively correct a housing component. As a remark, it should be noted that a housing-shading component is different from a housing-shading component as follows. The housing component is a component of a ray incident to a sensor device. The housing component is originated from the housing parts. On the other hand, the housing-shading component is used in comparison with the shading component caused by the optical system. The housing-shading component is a shading component caused by a housing component. In the following description, a housing-shading component is also referred to as a shading component caused by the housing. As a shading correction method focusing on a shading component caused by the housing parts, the infrared imaging apparatus adopts the following commonly-

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known technologies.

In accordance with a technology disclosed in Japanese Patent Publication No. Hei 7-32467 and referred to hereafter as prior art 1, the temperature of a lens housing employed in an optical system is measured by using a temperature sensor. A housing component is then computed from the measured temperature and a cubic angular table representing the lens housing's view seen from detector elements. The cubic angular table is stored in a memory. A shading component caused by the housing parts is corrected by subtracting a result of the computation from picture data. A shading component caused by the optical system is corrected by multiplying a result of the subtraction by irradiance distribution data stored in the memory.

In accordance with a technology disclosed in Patent No. 273196 and referred to hereafter as prior art 2, a picture signal of a plurality of lines which is generated by a linear array detector is stored. The picture signal is integrated and averaged for each element of the linear array detector and, by subjecting the averaged picture signal to a low-pass filtering, a shading component is extracted and removed from the original picture signal.

In accordance with a technology disclosed in

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Japanese Patent Laid-open No. Hei 5-292403 and referred to hereafter as prior art 3, an adjusted focus of an optical system is temporarily shifted to make a picture blurring. By this, even in the case where the radiation intensity of a scene is not distributed uniformly, uniform infrared rays are incident on detector elements and outputs of the detector elements are used as correction data.

In accordance with another technology disclosed in Japanese Patent Laid-open No. Hei 8-223484 and referred to hereafter as prior art 4, while a view axis of an image-taking unit is forcibly driven into a scanning movement, signals output by each infrared detector during a normal image-taking operation are averaged and smoothed. The averaged and smoothed signal is used for continuous shading correction in the normal image-taking operation. This technology is characterized that view axis scanning and signal smoothing are combined to exhibit the same effect as prior art 3. That is to say, by realizing a state equivalent to a case in which a uniform infrared ray is radiated to all detector elements on the average along the time axis even if the distribution of the radiation intensity of the scene is non-uniform, corrected data is obtained. To put it concretely, a

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deviation of each pixel from an average of all pixels is
added to or subtracted from picture data of an object of
correction. The deviation is a difference from an average
value calculated for all pixels in calibration data
created from smoothed data.

However, the prior arts have the following problems.

In accordance with prior art 1, a housing component
is computed by using a measured temperature of a lens
housing 10 and a cubic angular table representing the
lens housing 's view seen from detector elements as
described above. In the case of the housing component
caused by infrareds incident to detector elements from
the lens housing 10, there are a number of components
that can be calculated so that relatively accurate
correction is possible. In the case of the housing
component caused by an incident infrared ray originated
from infrared detectors/containers such as the window 12,
the cold shield 14, the inner shell 18 and the outer
shell 20, on the other hand, there are a number of
components that are difficult to calculate so that
accurate correction by calculation is impossible. A
housing component caused by an incident infrared ray from
an infrared detector container normally has a level which
is not negligible when compared with a housing component

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originated from infrared rays coming from the lens

housing 10. Thus, with prior art 1, the shading component

caused by the housing cannot be corrected with a high

degree of accuracy and accurate shading correction is

thus impossible. In addition, in the case of an infrared

imaging apparatus mounted on a movable structure of a

gimbal, which is required to have a small size and a fast

response such as a missile seeker, for example, prior art

1 also has a problem of deterioration of movable-unit

driving performance due to wires added for temperature

measurements.

In accordance with prior art 2, an attempt is made

to extract a shading component directly from an output of

each detecting elements during an image-taking process

without the need for a temperature measurement in order

to solve the problems encountered in prior art 1. However,

the low-pass filtering raises a problem of impossibility

to extract an accurate shading component. That is to say,

an incident component coming from a scene generally

contains a variety of spatial frequency components mixed

with each other. It is thus difficult to discriminate a

shading component and a scene component from each other

by using spatial frequencies. As a result, in actuality,

it is difficult to extract only the shading component.

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Prior art 3 raises a problem of temporary suspension of the objective to use the image-taking unit by an operation to shift the focus. In addition, prior art 3 also raises a problem of impossibility to implement accurate shading correction due to lost conformity of correction data. The non-conformity of correction data is caused by changes in housing temperature and scene temperature which occur since acquisition of the correction data.

While shading correction is possible, prior art 4 raises a problem of an altered scene picture which is resulted in as follows. If a scene component includes a structural distribution such as a ridge line resembling a brow of a hill, the scene component remains in smoothed data, making the data non-uniform. The non-uniform data is reflected in picture data obtained from correction processing.

SUMMARY OF THE INVENTION

It is thus an object of the present invention to provide an infrared imaging apparatus capable of reproducing an accurate scene picture by carrying out good shading correction even if the scene temperature and/or the housing temperature change.

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In accordance with an aspect of the present invention, there is provided an infrared imaging apparatus capable of carrying out shading correction of picture data obtained as a result of an image-taking process using a camera head comprising an optical system, a plurality of detector elements and a container for accommodating said detector elements, said infrared imaging apparatus characterized by including a first correction unit for creating corrected-sensitivity picture data by correction of shading components caused by the optical system to produce uniform scene components included in the picture data obtained as a result of an image-taking process of a uniform scene; a storage unit for storing a housing response profile for correcting a housing shading component caused by infrared rays radiated by the optical system and the container for each of the detector elements; and a second correction unit for creating corrected-housing-shading picture data by correction of housing-shading components based on the corrected-sensitivity picture data and the housing response profile for each of the detector elements.

Preferably, the second correction unit may correct a housing-shading component by executing the steps of assuming that, for each of the detector elements, the

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corrected-sensitivity picture data of the detector

element is a sum of a housing component of the detector

element and a second constant representing a scene

component where the housing component is a product of a

first constant and the housing response profile for the

detector element. Then finding the first constant's value

that minimizes a total obtained by summing square of a

difference the sum from the corrected-sensitivity picture

data related to the detector elements; and subtracting a

product of the housing response profile of the detector

element and the first constant from the corrected-

sensitivity picture data of the particular detector

element for each of the detector elements.

The above and other objects, features and

advantages of the present invention and the manner of

realizing them will become more apparent, and the

invention itself will best understood from a careful

study of the following description and appended claims

with reference to attached drawings showing some

preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing the principle of the

invention;

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FIG. 2 is a diagram showing the configuration of an infrared imaging apparatus implemented by a first embodiment of the present invention;

FIG. 3 is a diagram showing the configuration of a shading-correction unit employed in the infrared imaging apparatus shown in FIG. 2;

FIG. 4 is a diagram showing the configuration of a sensitivity-correction-calibration-data-creating unit employed in the shading-correction unit shown in FIG. 3;

FIG. 5 is an explanatory diagram used for describing a method of creating sensitivity-correction-calibration data;

FIG. 6 is a flowchart representing a process of creating sensitivity-correction-calibration data;

FIG. 7 is a diagram showing the configuration of a sensitivity-correction-processing unit employed in the shading-correction unit shown in FIG. 3;

FIG. 8 is a flowchart representing sensitivity correction;

FIG. 9 is a diagram showing a typical configuration of a housing-response-profile-creating unit employed in the infrared imaging apparatus shown in FIG. 2;

FIG. 10 is an explanatory diagram used for describing a method of creating a housing response

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profile;

FIG. 11 is a flowchart representing the method of creating a housing response profile;

FIG. 12 is a continuation flowchart representing the method of creating a housing response profile;

FIG. 13 is a diagram showing a typical housing response profile;

FIG. 14 is a diagram showing the configuration of a housing-component-intensity-processing unit employed in the shading-correction unit shown in FIG. 3;

FIG. 15 is a flowchart representing computation of a squared error;

FIG. 16 is a diagram showing the configuration of a housing-shading-correction-quantity-computing unit employed in the shading-correction unit shown in FIG. 3;

FIG. 17 is a flowchart representing computation of a combination of j and k that gives a minimum SE (j, k) and computation of a housing-shading correction quantity;

FIG. 18 is a diagram showing the configuration of a housing-shading-correction-processing unit employed in the shading-correction unit shown in FIG. 3;

FIG. 19 is a diagram showing an irradiance distribution of an infrared detector for a uniform scene;

FIG. 20 is a diagram showing signal components

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included in the output of a detector element;

FIG. 21 is a diagram showing data of a corrected-sensitivity picture of a uniform scene;

FIG. 22 is a diagram showing data of a corrected-sensitivity picture of a non-uniform scene;

FIG. 23 is a diagram showing the configuration of an infrared imaging apparatus implemented by a second embodiment of the present invention;

FIG. 24A is a diagram showing view axis scanning;

FIG. 24B is a diagram showing view axis scanning;

FIG. 25 is a diagram showing a typical scanning unit;

FIG. 26 is a diagram showing the configuration of a shading-correction unit employed in the infrared imaging apparatus shown in FIG. 23;

FIG. 27 is a diagram showing a smoothing-process unit employed in the shading-correction unit shown in FIG. 26;

FIG. 28 is a diagram showing the configuration of an infrared imaging apparatus implemented by a third embodiment of the present invention;

FIG. 29 is a diagram showing the configuration of a shading-correction unit employed in the infrared imaging apparatus shown in FIG. 28;

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FIG. 30 is a diagram showing the configuration of a local-correction-data-creating unit employed in the shading-correction unit shown in FIG. 29;

FIG. 31 is a diagram showing the configuration of an offset-correction unit employed in the shading-correction unit shown in FIG. 29;

FIG. 32 is a diagram showing the general configuration of a camera head;

FIG. 33 is a diagram showing a typical configuration of a camera head;

FIG. 34 is a diagram showing an infrared detector employed in the camera head shown in FIG. 32;

FIG. 35 is an explanatory diagram used for describing a role played by a cold shield; and

FIG. 36 is a diagram showing shading components.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to description of preferred embodiments of the present invention, the principle of the invention is described. FIG. 1 is a diagram showing the principle of the present invention. As shown in FIG. 1, an infrared imaging apparatus contains a first correction unit 34, a storage unit 36 and a second correction unit 38. The first correction unit 34 receives picture data taken by a

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camera head including an optical system, a plurality of detector elements and a container for accommodating the detector elements. When receiving picture data obtained as a result of photographing a uniform scene, the first correction unit 34 creates corrected-sensitivity picture data by correcting shading component caused by the optical system to make scene components included in the picture data uniform. Since shading component caused by the optical system is corrected to make scene components included in the picture data uniform, in the case of a uniform scene, all of scene components in the corrected-sensitivity picture data are same. The storage unit 36 is used for storing a housing response profile for correcting shading components caused by the housing components due to infrared rays radiated from the container for each of the detector elements and the lens-housing. The second correction unit 38 produces corrected-housing-shading picture data by correction of each shading component caused by the housing components based on the corrected-sensitivity picture data for each of the detector elements and the housing response profile. Thus, in the corrected-housing-shading picture data, shading components caused by the housing components is corrected. Various kinds of image processing carried out

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by the infrared imaging apparatus are based on the corrected-housing-shading picture data.

First Embodiment

FIG. 2 is a diagram showing the configuration of an infrared imaging apparatus implemented by a first embodiment of the present invention. Configuration elements of the first embodiment, which are virtually identical with those employed in the camera head 2 shown in FIG. 32, are denoted by the same reference numerals as the latter. This infrared imaging apparatus can be any image-taking apparatus as long as the image-taking apparatus is capable of correcting shading components caused by the optical system, which are included in data of a photographed picture, and capable of eliminating shading components caused by the housing components from the data.

As shown in FIG. 2, the infrared imaging apparatus is comprised of a camera head 2, an AD converter 40, a shading-correction unit 42 and a image-processing unit 44. The camera head 2 is essentially identical with the camera head 2 shown in FIG. 32. However, the infrared imaging apparatus implemented by this embodiment corrects shading components caused by the housing and shading components caused by the optical system. The AD converter

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40 converts analog picture signal generated by the infrared sensor 16 into digital picture data consisting of a predetermined number of bits, and supplies the digital picture data to the shading-correction unit 42. The number of bits composing the digital picture data is determined in dependence on the application. A control signal indicating the beginning of a frame and a clock signal synchronized with digital picture data are added to the digital picture data. A frame is fixed period of continuous screen data.

The shading-correction unit 42 has the following functions:

1: Correct shading components caused by the optical system from digital picture data on the basis of sensitivity-correction calibration data for each detector element. Shading components caused by the optical system are corrected by correction of variations in picture signal level, which are caused by differences in physical positions among the detector elements in the case of an input uniform scene, that is, by correction of digital picture data to produce new digital picture data having uniform scene-component levels. A uniform scene is a scene having uniform intensity levels.

2: Find housing components included in corrected-

sensitivity picture data by using a housing response profile.

3: Correct shading components caused by the housing, which are detected from corrected-sensitivity picture data.

Comprising components such as a CPU, a main memory, a ROM and a display unit, the image-processing unit 44 carries out image processing according to the application such as tracking of an observation target or a medical care, and displays information on the display unit. The shading-correction unit 42 can also be designed to comprise a CPU, a main memory and a ROM. In this case, a CPU can be shared by the shading-correction unit 42 and the image-processing unit 44. By sharing a CPU with the image-processing unit 44, the shading-correction unit 42 can be implemented with ease at a low cost. A sensitivity-correction-calibration-data-creating unit 46 shown as a dashed-line block in FIG. 2 is a functional unit for executing a pre-operation function preceding an operation to correct shading components caused by the optical system. By the same token, a housing-response-profile-creating unit 48 also shown as a dashed-line block in FIG. 2 is a functional unit for executing a pre-operation function preceding an operation to correct

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shading components caused by the housing. A pre-operation function is a function not necessarily required during operation. The sensitivity-correction-calibration-data-creating unit 46 and the housing-response-profile-creating unit 48 can be mounted on the infrared imaging apparatus. In the case of this embodiment, however, the sensitivity-correction-calibration-data-creating unit 46 and the housing-response-profile-creating unit 48 are provided as separate units instead of being mounted on the infrared imaging apparatus. In the case of an infrared imaging apparatus installed at a narrow location in an application wherein it is desired to reduce the weight of the infrared imaging apparatus as is the case with a missile seeker or the like, the functions of the sensitivity-correction-calibration-data-creating unit 46 and the housing-response-profile-creating unit 48 are difficult to implement in such an environment. For this reason, the sensitivity-correction-calibration-data-creating unit 46 and the housing-response-profile-creating unit 48 are provided as separate units as is the case with this embodiment.

Provided separately from the infrared imaging apparatus as described above, the sensitivity-correction-calibration-data-creating unit 46 creates sensitivity-

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correction calibration data to be used in correction of

shading components caused by the optical system before

the operation of the infrared imaging apparatus. The

correction of shading components caused by the optical

system is also referred to as sensitivity correction. By

the same token, also provided separately from the

infrared imaging apparatus as described above, the

housing-response-profile-creating unit 48 creates housing

response profiles to be used in correction of shading

components caused by the housing before the operation of

the infrared imaging apparatus.

A housing component is proportional to a housing

radiation power. Assume that the radiation power of a

scene is 0 and digital picture data for a detector

element i is HSi1 at a housing radiation power of W1. In

this case, digital picture data HSi2 for the detector

element i at a housing radiation power of W2 is HSi2 =

(W2/W1) x HSi1. The proportional constant of W2/W1 holds

true of all detector elements instead of being limited to

only the detector element i. Thus, the housing component

of a detector element i at any arbitrary temperature in

the camera head 2 is a fixed number of times the digital

picture data HSi1. It is therefore obvious that the

profile needs to be made a fixed number of times the

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digital picture data HSil for a detector element i.
However, the actual profile value and the physical
dimensions are determined from a point of view showing
that their calculation is easy as will be described later.

FIG. 3 is a diagram showing the configuration of
the shading-correction unit 42 employed in the infrared
imaging apparatus shown in FIG. 2. As shown in FIG. 3,
the shading-correction unit 42 is comprised of a
sensitivity-correction-processing unit 52, a housing-
response-profile storage memory 56, a housing-component-
intensity-processing unit 58, a housing-shading-
correction-quantity-computing unit 60 and a housing-
shading-correction-processing unit 62. As will be
described later, the sensitivity-correction-processing
unit 52 creates corrected-sensitivity picture data by
using the sensitivity-correction calibration data which
has been created by the sensitivity-correction-
calibration-data-creating unit 46 employed in the
infrared imaging apparatus as shown in FIG. 2 prior to
the operation of the infrared imaging apparatus.

The sensitivity-correction calibration data
includes offset-correction calibration data, gain-
correction calibration data and average-value data. Set
for each detector element i, the offset-correction

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calibration data is digital picture data L_i including
housing components output by each detector element i at T_a
and T_L where notation T_a is the temperature of the camera
head 2 and notation T_L is a relatively low temperature of
a uniform scene. The average value data is an average
value L of pieces of digital picture data L_i of detector
elements i. The gain-correction calibration data g_i is
set for each detector element i. It is digital picture
data L_i including housing components output by each
detector element i at T_a and T_H where notation T_a is the
temperature of the camera head 2 as described above, and
notation T_H is a relatively high temperature of a uniform
scene. The gain-correction calibration data g_i is given
by the following equation:

$$g_i = (H - L)/(H_i - L_i) \qquad (1)$$

where notation H is an average value of pieces of
digital picture data H_i of detector elements i and
notation L is an average value of pieces of digital
picture data L_i of detector element i.

FIG. 4 is a diagram showing the configuration of
the sensitivity-correction-calibration-data-creating unit
46 employed in the shading-correction unit shown in FIG.
3. As shown in FIG. 4, the sensitivity-correction-
calibration-data-creating unit 46 is comprised of a low-

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temperature-uniform-data acquisition unit 70, a high-temperature-uniform-data acquisition unit 72, an offset-correction-calibration-data-creating unit 74, a gain-correction-calibration-data-creating unit 76 and an average-value-computing unit 78. FIG. 5 is an explanatory diagram used for describing a method of creating sensitivity-correction-calibration data. FIG. 6 is a flowchart representing a process of creating sensitivity-correction-calibration data.

(a) Data acquisition processing

In order to create sensitivity-correction calibration data, a black-body-radiator 90 is placed in front of the camera head 2 as shown in FIG. 5. The black-body-radiator 90 is a typical radiating body used for obtaining a uniform scene. For example, the black-body-radiator 90 is formed by applying a black coating material to a metallic plate which is made of typically aluminum and has a rough surface. A temperature control unit 92 controls the temperature of the black-body-radiator 90.

At the first step S2 of the flowchart shown in FIG. 6, a picture of the black-body-radiator 90 is taken at T_a of typically 10 degrees Celsius and T_L of typically 10 degrees Celsius where notation T_a denotes a predetermined

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temperature of the camera head 2, and notation T_L denotes
a relatively low temperature of the black-body-radiator
90 respectively. The low-temperature-uniform-data
acquisition unit 70 acquires the output level Li of each
detector element i under above low temperature condition,
and stores the level Li in a memory.

At the next step S4, the high-temperature-uniform-
data acquisition unit 72 takes a picture of the black-
body-radiator 90 at the temperature T_a of the camera head
2 and a high temperature T_H of typically 30 degrees
Celsius where notation T_H denotes a relatively high
temperature of the black-body-radiator 90. The high-
temperature-uniform-data acquisition unit 72 acquires the
output level Hi of each detector element i under above
high temperature condition, and stores the level Hi in
the memory.

(b) Calculation processing

At the next step S8, the gain-correction-
calibration-data-creating unit 76 computes an average
value L of output levels Li for all detector elements i.
At the next step S10, the gain-correction-calibration-
data-creating unit 76 computes an average value H of
output levels Hi for all detector elements i. At the next
step S12, the gain-correction-calibration-data-creating

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unit 76 computes gain-correction calibration data gi expressed by Eq. (1) for each detector element i. The output levels Hi and Li as well as the average values L and H each contain shading components caused by the housing. Since the temperature T_a of the camera head 2 is not changed, however, the housing radiation power at the low temperature T_L of the black-body-radiator 90 is the same as the housing radiation power at the high temperature T_H of the black-body-radiator 90. Thus, shading components caused by the housing, which are contained in the relatively high output level Hi, are the same as those contained in the relatively low output level Li. By the same token, shading components caused by the housing, which are contained in the average value H, are the same as those contained in the average value L. As a result, the gain-correction calibration data gi does not contain shading components caused by the housing.

(c) Data writing processing

At the next step S13, the offset-correction-calibration-data-creating unit 74 stores the relatively low output level Li for each of the detector elements i in an offset-correction-calibration-data storage memory 80. At the next step S14, the gain-correction-calibration-data-creating unit 76 stores the gain-

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correction calibration data gi for each of the detector

elements i in a gain-correction-calibration-data storage

memory 82. At the next step S16, the average-value-

computing unit 78 stores the average value L in an

average-value storage memory 84.

FIG. 7 is a diagram showing the configuration of

the sensitivity-correction-processing unit 56 employed in

the shading-correction unit 42 shown in FIG. 3. As shown

in the figure, the sensitivity-correction-processing unit

56 includes the offset-correction-calibration-data

storage memory 80, the gain-correction-calibration-data

storage memory 82, the average-value storage memory 84,

an adder 90, a multiplier 92 and an adder 94. FIG. 8 is a

flowchart representing sensitivity correction. As shown

in the figure, at a step S20 the adder 90 inputs digital

picture data OALLi of a detector element serially

outputted by the AD converter 40 in synchronization with

a clock signal shown in none of the figures. At the next

step S22, the adder 90 reads offset-correction

calibration data Li of the detector element i from the

offset-correction-calibration-data storage memory 80. At

the next step S24, the adder 90 subtracts the offset-

correction calibration data Li from the offset-correction

calibration data Li to result in a difference (OALLi −

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Li). At the next step S26, the multiplier 92 reads gain-correction calibration data gi of the detector element i from the gain-correction-calibration-data storage memory 82. At the next step S28, the multiplier 92 multiplies the gain-correction calibration data gi by the difference (OALLi - Li) to give a product (OALLi - Li) x gi. At the next step S30, the adder 94 reads the average value L from the average-value storage memory 84 for use in computation of the value of an expression ((OALLi - Li) x gi + L) representing picture data Xi, that is, Xi = ((OALLi - Li) x gi + L). It should be noted that the average value L is computed as an average of pieces of offset-correction calibration data Li of all detector elements i.

The following description explains the fact that the picture data Xi has indeed completed sensitivity correction. In the description of the present invention, sensitivity correction is defined as correction of optical shading, which is caused by difference of physical positions of detector elements and scene component is not uniform in the case of a uniform scene and the detector elements with uniform characteristics, and correction of variations in characteristics of detector elements. In the case of a uniform scene,

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sensitivity correction is carried out to make scene

components uniform over detector elements.

In the sensitivity correction, the following

equations hold true: $OALLi = SNi + HSi$, $Li = SNLi + HSLi$

and $L = SNL + HSL$ where notations SN and HS denote the

scene component and the housing component respectively.

In this case, $Xi = (SNi - SNLi) \times gi + SNL + (HSi - HSLi)$

$\times gi + HSL$. Since the gain-correction calibration data gi

does not include shading components caused by the housing,

$((SNi - SNLi) \times gi + SNL)$ is about uniform for all

detector elements in the case of a uniform scene, and

regarded as a scene component completing sensitivity

correction. On the other hand, $((HSi - HSLi) \times gi + HSL)$

has a value different from the housing component HSi due

to sensitivity correction. However, the greater the value

of HSi, the greater the value of $((HSi - HSLi) \times gi +$

$HSL)$. Thus, the expression $((HSi - HSLi) \times gi + HSL)$

represents a characteristic of HSi. As will be described

later, this value is eliminated as a shading component

caused by the housing. Thus, while the picture data Xi

includes housing components, Xi is data completing

sensitivity correction. In the following description,

this picture data Xi is referred to as corrected-

sensitivity picture data. In addition, even in the case

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of a non-uniform scene, the digital picture data is corrected in accordance with the picture-data level of the digital picture data OALLi by using the gain-correction calibration data gi which does not include shading components caused by the housing. Thus, the digital picture data is subjected to sensitivity correction according to the irradiance level of the scene.

FIG. 9 is a diagram showing a typical configuration of the housing-response-profile-creating unit 48 employed in the infrared imaging apparatus shown in FIG. 2. As shown in FIG. 9, the housing-response-profile-creating unit 48 is comprised of a low-temperature-housing-data acquisition unit 100, a high-temperature-housing-data acquisition unit 102, a low-temperature-black-body-radiator-data acquisition unit 104, a high-temperature-black-body-radiator-data acquisition unit 106, a housing-data-difference-processing unit 108, a black-body-radiator-data-difference-processing unit 110 and a housing-response-profile-computing unit 112. FIG. 10 is an explanatory diagram used for describing a method of creating a housing response profile. FIGS. 11 and 12 show a flowchart representing the method of creating a housing response profile.

(a) Data acquisition processing

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In order to create a housing response profile, the
camera head 2 is accommodated in a temperature stabilized
oven 120 as shown in FIG. 10. The temperature of the
temperature stabilized oven 120 is controlled by an oven-
temperature control unit 122. The black-body-radiator 90
is placed in front of the camera head 2. The temperature
of the black-body-radiator 90 is controlled by a black-
body-radiator-temperature control unit 92.

At the first step S40 of the flowchart shown in FIG.
11, a picture of the black-body-radiator 90 is taken at T_t
of typically 10 degrees Celsius and T_L of typically 10
degrees Celsius where notation T_L denote a relatively low
temperature of the camera head 2 and notation Tt denotes
a predetermined temperature of the black-body-radiator 90.
The low-temperature-shading-data acquisition unit 100
acquires the relatively high output level HLi of each
detector element i under above condition, and stores the
level HLi in a memory.

At the next step S42, a picture of the black-body-
radiator 90 is taken at the temperature Tt and a
temperature T_H of typically 30 degrees Celsius where
notation Th denotes a relatively high temperature of the
camera head 2. The high-temperature-shading-data
acquisition unit 102 acquires the relatively high output

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level HHi of each detector element i under above

condition, and stores the level HHi in the memory.

At the next step S44, a picture of the black-body-

radiator 90 is taken at the temperatures T_a and T_L, and

the output level SLi of each detector element i is

acquired where notation Ta denotes a predetermined

temperature of the camera head 2 and notation T_L denotes a

relatively low temperature of the black-body-radiator 90.

At the next step S46, a picture of the black-body-

radiator 90 is taken at the temperature T_a of the camera

head 2 and a temperature T_H, and the output level SHi of

each detector element i is acquired where notation T_H

denotes a relatively high temperature of the black-body-

radiator 90. The outputs levels HLi, HHi, SLi and SHi are

each corrected-sensitivity picture data output by the

sensitivity-correction-processing unit 52.

(b) Calculation processing

At the next step S52, the housing-data-difference-

processing unit 108 computes an output-level difference $\triangle$

Hi (= HHi - HLi) of each detector element i. Since the

output levels HLi and HHi are measured at the constant

temperature T_t of the black-body-radiator 90, scene

components from the black-body-radiator 90, which are

included in the relatively low output level HLi, are the

same as those included in the relatively high output

level HHi. Thus, the output-level difference $\triangle$Hi

comprises only housing-shading components caused by a

temperature change $\triangle T (= T_H - T_L)$ of the camera head 2.

At the next step S54, the black-body-radiator-data-

difference-processing unit 110 computes an output-level

difference $\triangle$Si(= SHi - SLi) of each detector element i.

The output levels SLi and SHi, which are measured at the

constant temperature Ta of the camera head 2, have been

subjected to sensitivity correction for scene components.

Thus, the output-level difference $\triangle$Si is fixed

independently of the detector elements i.

Let notation $\triangle$HP denote a change in radiance

accompanying a change in housing (camera-head)

temperature $(T_H - T_L)$ where the radiance is defined as an

infrared radiation power expressed in terms of $W/cm^2.sr$.

In this case, HRi(= $\triangle$Hi/$\triangle$HP) expressed in terms of

$LSB/(W/cm^2.sr)$ is a change in output level per unit

housing radiation power where the output level is a level

output by each detector element i.

By the same token, let notation $\triangle$SP denote a

change in radiance accompanying a change in black-body-

radiator temperature $(T_H - T_L)$. In this case, SRi(= $\triangle$Si =

(SHi - SLi)/$\triangle$SP = $\triangle$S/$\triangle$SP) expressed in terms of

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LSB/(W/cm^2.sr) is a change in output level per black-body-radiator unit radiation power where the output level is a level output by each detector element i. Since the change in housing temperature $(T_H - T_L)$ is made equal to the change in black-body-radiator temperature $(T_H - T_L)$, $\triangle$SP = $\triangle$HP. It should be noted that, in the above description, the housing and the black-body-radiator 90 are assumed to have black-body characteristics of the same type. At the next step S56, the housing-response-profile-computing unit 112 computes a housing response profile PROFi (= HRi/SR = ($\triangle$Hi/$\triangle$HP)/($\triangle$S/$\triangle$SP) = $\triangle$Hi/$\triangle$S) for each detector element i.

(c) Data writing processing

At the next step S58, the housing-response-profile-computing unit 112 stores the housing response profile PROFi computed for each detector element i in the housing-response-profile storage memory 56.

The housing response profile PROFi is a ratio of a housing component to a scene component where the scene component is an output of a detector element i per black-body-radiator unit radiation power and the housing component is an output of the detector element i per unit housing radiation power. It is nice to have a housing response profile PROFi equal to a fixed number of times $\triangle$

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Hi. By dividing $\triangle$Hi by $\triangle$S, however, the physical

dimensions can be made dimensionless, and the computation

of a housing component included in corrected-sensitivity

picture data can thus be made simple. In addition, it

becomes possible to set a standard for estimating an

upper limit of the ratio of a housing component included

in the corrected-sensitivity picture data to a scene

component.

FIG. 13 is a diagram showing a typical housing

response profile. In the diagram, the horizontal axis

represents the number i of the detector elements and the

vertical axis represents the housing profile response. To

put in detail, FIG. 13 is shows a housing response

profile PROFi of 100 detector elements on the center line

of the infrared sensor 16 comprising detector elements

laid out to form a 100 x 100 matrix. The housing response

profile is increasing, starting from a detector element

50 in the middle of the center line toward both the ends

of the center line because detector elements at the ends

each have a larger housing perspective angle.

The housing-component-intensity-processing unit 58

computes a constant Ih for calculating a housing

component from the housing response profile PROFi. For a

detector element i, let notation MDOALLi denote the level

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of the corrected-sensitivity picture data, notation MDSNi denote the level of picture data for a scene component in the corrected-sensitivity picture data and notation MDHSi denote the level of picture data for a housing component. In this case, Eq. (2) expressing a relation among MDOALLi, MDSNi and MDHSi below holds true.

$$MDOALLi = MDSNi + MDHSi \quad (2)$$

Since the picture-data level MDHSi is a product of the housing response profile PROFi stored in the housing-response-profile storage memory 56 and the constant Ih, Eq. (2) can be re-expressed by Eq. (3) as follows:

$$MDOALLi = MDSNi + Ih \times PROFi \quad (3)$$

In the case of a scene with uniform radiance, the scene incident component MDSNi has a fixed value MDSN0 independent of the detector element i. Thus, simultaneous equations (4) and (5) can be derived from Eq. (3) for detector elements 1 and 2 respectively as follows:

$$MDOALL1 = MDSN0 + Ih \times PROF1 \quad (4)$$

$$MDOALL2 = MDSN0 + Ih \times PROF2 \quad (5)$$

As a solution to the simultaneous equations (4) and (5), the value of Ih can be obtained as expressed by Eq. (6) as follows:

$$Ih = (MDOALL1 - MDOALL2)/(PROF1 - PROF2) \quad (6)$$

Noises are superposed on actual picture data. Thus,

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even in the case of a uniform scene, it is generally

difficult to find a strict solution to such simultaneous

equations. For this reason, a technique of finding an

approximate solution is required. In addition, the

technique needs to be applicable to not only a uniform

scene but also a locally uniform scene. Therefore, in

this embodiment, simultaneous equations are established

for detector elements in a picture data area set in

advance. Then, by using the least-square method, an

approximate solution to the simultaneous equations can be

found.

FIG. 14 is a diagram showing the configuration of

the housing-component-intensity-processing unit 58

employed in the shading-correction unit 42 shown in FIG.

3. As shown in FIG. 14, the housing-component-intensity-

processing unit 58 comprises a RAM 130, an average-value-

computing unit 132, a squared-error-computing unit 134

and a constant-determining unit 136. The RAM 130 is a

memory for storing picture data. It should be noted that,

while the picture data stored in the RAM 130 can be all

picture data, data which is included in a picture data

area set in advance and is used by the squared-error-

computing unit 134 can serve as sufficient stored picture

data. The average-value-computing unit 132 computes an

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average value MOUT of data included in the picture data

area set in advance by the squared-error-computing unit

134. The squared-error-computing unit 134 has the

following functions:

1: Set a tentative constant Ihj and a tentatively set

scene level ISk.

2: Compute a squared error SE (j, k) which is a sum of an

expression $\{ISk -(MDOALLi -Ihj \times PROFi)\}^2$ computed with

respect to i in the picture data area set in advance. The

picture data area set in advance can be the output

picture data area of all detector elements of the

infrared sensor 16. At any rate, the precision of the

constants is required. In addition, it is necessary to

minimize the picture data area set in advance so that the

computation can be carried out at a high speed. Since

housing components are distributed into concentric

circles with their centers all coinciding with a detector

element in the middle, data of detector elements on a

line (a column or a row) is taken. In this case, it is

desired to select a line with an extremely uniform scene

distribution. In the case of an application with the sky

serving as the background, since the scene distribution

on a horizontal line is more uniform than that on a

vertical line, data of detector elements on a horizontal

line is taken. An example of the application with the sky

serving as the background is an air-to-air missile seeker.

3: Carry out the computation of function 2 for every

possible combination of each tentative constant Ihj and

the tentatively set scene level ISk.

FIG. 15 is a flowchart representing computation of

a squared error. Details of the squared-error computation

are explained as follows. As shown in the figure, the

flowchart begins with a step S80 at which the tentative

constant Ih is set at Ihst (= MOUT/M), the tentatively

set scene level Is is set at Isst (= MOUT/M), where M =

50, whereas the computation counts j and k are each

initialized at 0. Notation M denotes a maximum

computation count having a suitable value such as 50. At

the next step S82, the tentative constant Ihj is set at

Ihst x (j + 1). Then, at the next step S84, the

tentatively set scene level ISk is set at Isst x (k + 1).

Subsequently, at the next step S86, a squared error SE (j,

k) of picture data after tentative shading correction

relative to the tentative scene level is computed by

using the following equation:

$$SE~(j,~k) = \Sigma~\{ISk~-(MDOALLi~-Ihj~x~PROFi)\}^{2}$$

where notation Σ denotes summation for all detector

elements i along a horizontal-direction line at the

center.

Then, at the next step S88, the computation count k
is incremented by 1 to give an updated value of (k + 1)
as denoted by notation (k = k + 1) in the flowchart shown
in FIG. 15. The flow of the squared-error computation
then goes on to a step S90 to form a judgment as to
whether or not the count value k is greater than the
maximum count value M (k > M). If the count value k is
not greater than the maximum count value M (k $\leqq$ M), the
flow of the squared-error computation goes back to the
step S84. If the count value k is greater than the
maximum count value M (k > M), on the other hand, the
flow of the squared-error computation goes on to a step
S92. At the step S92, the computation count j is
incremented by 1 to give an updated value of (j + 1) as
denoted by notation (j = j + 1) in the flowchart shown in
FIG. 15. Then, at the next step S94, the computation
count k is set at an initial value of 0. The flow of the
squared-error computation then goes on to a step S96 to
form a judgment as to whether not the count value j is
greater than the maximum count value M (j > M). If the
count value j is not greater than the maximum count value
M (j $\leqq$ M), the flow of the squared-error computation goes
back to the step S82. If the count value j is greater

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than the maximum count value M (j > M), on the other hand,

the flow of the squared-error computation goes on to a

step S98. At the step S98, processing represented by a

flowchart to be described later is carried out to find a

combination of the computation count j and the

computation count k that minimizes the squared error SE

(j, k). The constant-determining unit 136 computes the

constant value Ih (= Ihst x (J + 1)) for the combination

of J and K where notations J and K are respectively the

computation counts j and k that minimize the squared

error SE (j, k) computed by the squared-error-computing

unit 134.

FIG. 16 is a diagram showing the configuration of

the housing-shading-correction-quantity-computing unit 60

employed in the shading-correction unit 42 shown in FIG.

3. As shown in the figure, the housing-shading-

correction-quantity-computing unit 60 has a multiplier

140. The multiplier 140 computes a product of the housing

response profile PROFi and the constant Ih for all

detector elements i.

FIG. 17 is a flowchart representing computation of

a combination of the computation counts j and k that

gives a minimum squared error SE (j, k) and computation

of a housing-shading correction quantity. As shown in the

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figure, the flowchart begins with a step S100 at which

the computation counts j and k are each initialized at 0

($j = 0$ and $k = 0$) whereas a minimum value MIN of the

squared error SE (j, k) is initialized at 4,095 (MIN =

4,095). At the next step S102, the computation count j is

incremented by 1 to give an updated value of ($j + 1$) as

denoted by notation ($j = j + 1$) in the flowchart shown in

FIG. 17. Then, at the next step S104, the computation

count k is incremented by 1 to give an updated value of

($k + 1$) as denoted by notation ($k = k + 1$) in the

flowchart. Subsequently, at the next step S106, the

squared error SE (j, k) is substituted for the minimum

value MIN if SE (j, k) < MIN. If SE (j, k) $\geq$ MIN, on the

other hand, nothing is done. The flow of the processing

then goes on to a step S110 to form a judgment as to

whether or not the computation count k is greater than

the maximum value M ($k > M$). If the computation count k

is not greater than the maximum value M ($k \leq M$), the flow

of the processing goes back to the step S104. If the

computation count k is greater than the maximum value M

($k > M$), on the other hand, the flow of the processing

goes on to the step S114. At the step S114, the

computation count k is reset at the initial value of 0 (k

= 0). The flow of the processing then goes on to a step

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S116 to form a judgment as to whether or not the

computation count j is greater than the maximum

computation count M (j > M). It should be noted that the

maximum computation count M is the same as that used in

the flowchart shown in FIG. 15. If the computation count

j is not greater than the maximum value M (j $\leqq$ M), the

flow of the processing goes back to the step S102. If the

computation count k is greater than the maximum value M

(j > M), on the other hand, the flow of the processing

goes on to the step S118. At the step S118, the constant-

determining unit 136 computes the constant value Ih (=

Ihst x (J + 1)) for the combination of J and K where

notations J and K are respectively the computation counts

j and k that minimize the squared error SE (j, k)

computed by the squared-error-computing unit 134. At the

next step S120, the housing component MDHSi (= Ih x

PROFi) is computed for each detector element i.

FIG. 18 is a diagram showing the configuration of

the housing-shading-correction-processing unit 62

employed in the shading-correction unit 42 shown in FIG.

3. As shown in FIG. 18, the housing-shading-correction-

processing unit 62 has an adder 150. The adder 150

subtracts the housing component MDHSi from the corrected-

sensitivity picture data level MDOALLi for each detector

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element i in order to correct shading components caused by the housing.

The operation of the infrared imaging apparatus shown in FIG. 2 is described as follows.

(1) Creation of sensitivity-correction calibration data

Sensitivity-correction calibration data is created by the sensitivity-correction-calibration-data-creating unit 46 and stored in ROMs, namely, the offset-correction-calibration-data storage memory 80, the gain-correction-calibration-data storage memory 82 and the average-value storage memory 84, prior to the operation of the infrared imaging apparatus as follows.

First of all, as shown in FIG. 5, a picture of the black-body-radiator 90 is taken by using the camera head 2 at Ta of typically 10 degrees Celsius and T_L of typically 10 degrees Celsius where notation T_a denotes a predetermined temperature of the camera head 2 and notation T_L denotes a relatively low temperature of the black-body-radiator 90. The AD converter 40 then converts an analog picture signal output by the camera head 2 into digital picture data. The sensitivity-correction-calibration-data-creating unit 46 inputs a relatively low level Li of the digital picture data for each detector element i under above condition and stores the level Li

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into the offset-correction-calibration-data storage

memory 80. The sensitivity-correction-calibration-data-

creating unit 46 then computes an average value L of the

relatively low output levels Li for all detector elements

i and stores the average value L into the average-value

storage memory 84.

Then, a picture of the black-body-radiator 90 is

taken by using the camera head 2 at the predetermined

temperature T_a and a temperature T_H of typically 30

degrees Celsius where notation T_H denotes a relatively

high temperature of the black-body-radiator 90. The AD

converter 40 then converts an analog picture signal

output by the camera head 2 into digital picture data.

The sensitivity-correction-calibration-data-creating unit

46 inputs a relatively high level Hi of the digital

picture data for each detector element i, and computes

gain-correction calibration data gi, storing the gain-

correction calibration data gi in the gain-correction-

calibration-data storage memory 82.

(2) Creation of a housing response profile

A housing response profile is created by the

housing-response-profile-creating unit 48 prior to the

operation of the infrared imaging apparatus as described

below and stored in a ROM, namely, the housing-response-

48

profile storage memory 56. As shown in FIG. 10, a picture

of the black-body-radiator 90 is imaged by using the

camera head 2 at T_t of typically 10 degrees Celsius and T_L

of typically 10 degrees Celsius where notation T_L denotes

a relatively low temperature of the camera head 2 and

notation T_t denotes a predetermined temperature of the

black-body-radiator 90. The AD converter 40 then converts

an analog picture signal output by the camera head 2 into

digital picture data. Subsequently, the digital picture

data is subjected to sensitivity correction in the

sensitivity-correction-processing unit 52 to produce

corrected-sensitivity picture data. The housing-response-

profile-creating unit 48 then inputs a relatively low

level HLi of the corrected-sensitivity picture data for

each detector element i.

Then, a picture of the black-body-radiator 90 is

imaged by using the camera head 2 at the predetermined

temperature T_t and a temperature T_H of typically 30

degrees Celsius where notation T_H denotes a relatively

high temperature of the camera head 2. The AD converter

40 then converts an analog picture signal output by the

camera head 2 into digital picture data. Subsequently,

the digital picture data is subjected to sensitivity

correction in the sensitivity-correction-processing unit

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52 to produce corrected-sensitivity picture data. The
housing-response-profile-creating unit 48 then inputs a
relatively high level HHi of the corrected-sensitivity
picture data for each detector element i.

On the other hand, a picture of the black-body-
radiator 90 is imaged by using the camera head 2 at T_a of
typically 10 degrees Celsius and T_L of typically 10
degrees Celsius where notation T_a denotes a predetermined
temperature of the camera head 2 and notation T_L denotes a
relatively low temperature of the black-body-radiator 90.
The AD converter 40 then converts an analog picture
signal output by the camera head 2 into digital picture
data. Subsequently, the digital picture data is subjected
to sensitivity correction in the sensitivity-correction-
processing unit 52 to produce corrected-sensitivity
picture data. The housing-response-profile-creating unit
48 then inputs a relatively low level SLi of the
corrected-sensitivity picture data for each detector
element i.

Then, a picture of the black-body-radiator 90 is
imaged by using the camera head 2 at the predetermined
temperature T_a and a temperature T_H of typically 30
degrees Celsius where notation T_H denotes a relatively
high temperature of the black-body-radiator 90. The AD

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converter 40 then converts an analog picture signal

output by the camera head 2 into digital picture data.

Subsequently, the digital picture data is subjected to

sensitivity correction in the sensitivity-correction-

processing unit 52 to produce corrected-sensitivity

picture data. The housing-response-profile-creating unit

48 then inputs a relatively high level SHi of the

corrected-sensitivity picture data for each detector

element i.

Subsequently, the housing-response-profile-creating

unit 48 computes an output-level differences $\triangle$Hi (= HHi -

HLi) and $\triangle$Si (= SHi - SLi) for each detector element i of

the infrared sensor 16. As described above, the output-

level difference $\triangle$Si is an output-level difference $\triangle$S

uniform for all detector elements i. Then, the housing-

response-profile-creating unit 48 computes a housing

response profile PROFi (= $\triangle$Hi/$\triangle$S) and stores the housing

response profile PROFi in the housing-response-profile

storage memory 56.

(3) Operation of infrared imaging apparatus

In an infrared imaging apparatus applied to a

variety of fields including a missile seeker, a lens

images a scene on detector elements of the infrared

sensor 16 and generates signals from detector elements i

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of the infrared sensor 16 to produce an analog signal

according to the intensity of the scene. At that time,

the analog signal includes housing radiation components

radiated from the housing parts including the lens

housing 10, the inner shell 18 and the outer shell 20.

The AD converter 40 converts the analog signal into

digital picture data, and supplies the digital picture

data to the shading-correction unit 42.

FIG. 19 is a diagram showing an irradiance

distribution of an infrared detector comprising 100 x 100

detector elements for a uniform scene. As shown in FIG.

19, in the case of a uniform scene, the scene irradiance

distribution at detector elements i becomes concentric

circles centering at a detector element in the center of

the infrared sensor 16. That is to say, output levels of

detector elements at the same distance from the center

detector element are all the same level.

FIG. 20 is a diagram showing signal components

included in the output of a detector element in the case

of a uniform scene. The horizontal axis represents the

number i of the detector element and the vertical axis

represents the level of the picture data. FIG. 20 shows

components included in digital picture data of 100

detector elements located on a center line L oriented in

the horizontal direction in FIG. 19. A curve OALL

represents digital picture data converted by the AD

converter 40, a curve SN represents scene components

caused only by shading of the optical system without

characteristic variations of detector elements, a curve

HS represents housing components and a curve UNE

represents components caused by characteristic variations

of detector elements. For a detector element i, a suffix

i is appended as in $OALL_i$, SN_i, HS_i and UNE_i for denoting

respectively digital picture data generated by the AD

converter 40, scene components caused only by shading of

the optical system without characteristic variations of

detector elements, housing components and components

caused by characteristic variations for the detector

element i. In this case, $OALL_i = SN_i + HS_i + UNE_i$. As

shown in FIG. 20, the curve SN indicates that scene

components are not uniform even in the case of a uniform

scene. Instead, the curve SN displays a peak at the

center of the infrared sensor 16 and declines at detector

elements separated away from the center. This phenomenon

is caused by shading of the optical system.

(a) Sensitivity correction processing

The sensitivity-correction-processing unit 52

computes the value of an expression ((Digital picture

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data OALLi -Offset-correction calibration data Li) x

Gain-correction calibration data gi + Average value L) to

output corrected-sensitivity picture data for each

detector element i. Thus, as described above, components

in a scene, which are caused by shading of the optical

system and the variation components UNE shown in FIG. 20,

are corrected so that, in the case of a uniform scene,

scene components become approximately uniform. The output

of the sensitivity-correction-processing unit 52 is

called corrected-sensitivity picture data.

FIG. 21 is a diagram showing corrected-sensitivity

picture data for a uniform scene. The horizontal axis

represents the number i of the detector element and the

vertical axis represents the level of the picture data. A

curve MDOALL represents corrected-sensitivity picture

data and a curve MDSN represents corrected scene

components in the corrected-sensitivity picture data. A

curve MDHS represents corrected housing components. As

shown in FIG. 21, in the case of a uniform scene, the

corrected components MDSN are uniform independently of

detector elements i. The curve MDOALL representing

corrected-sensitivity picture data is a sum of the curve

MDSN representing corrected scene components and the

curve MDHS representing corrected housing components.

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FIG. 22 is a diagram showing data of a corrected-sensitivity picture of a non-uniform scene. The horizontal axis represents the number i of the detector element and the vertical axis represents the level of the picture data. As shown in FIG. 22, in the case of a non-uniform scene, the corrected components MDSN are not uniform independently of detector element i. As described above, however, in order to make picture data conform to the irradiance level of scene components, shading components caused by the optical system and components caused by characteristic variations of detector elements are corrected so that the curve MDOALL representing corrected-sensitivity picture data is equal to a sum of the curve MDSN representing corrected components in the corrected-sensitivity picture data and the curve MDHS representing housing components.

(b) Housing shading correction

(b-1) Housing component intensity processing

The housing-component-intensity-processing unit 58 computes an average value MOUT of pieces of corrected-sensitivity picture data MDOALLi for each frame where the pieces of corrected-sensitivity picture data MDOALLi are pieces of data of detector elements in a predetermined area of the infrared sensor 16. An example of the

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predetermined area is a center line of the infrared

sensor 16. A frame is fixed period such as 16 ms of

continuous screen data output from the infrared sensor 16.

For the corrected-sensitivity picture data MDOALLi in a

predetermined area of each frame, the following equation

is assumed: MDOALLi = IS + MDHSi, where notation IS

denotes scene components included in the corrected-

sensitivity picture data MDOALLi in the case of a uniform

scene, and notation MDHSi denotes housing components. By

the way, the following equation holds true: MDHSi = Ih x

PROFi. The squared error SE (j, k) is computed as a value

of an equation $\{ISk -(MDOALLi -Ihj \times PROFi)\}^2$ where

notation Ihj denotes the tentative constant and notation

ISk denotes the initial tentatively set scene level in

the predetermined area. It should be noted that the

tentative constant ISk can have a value ranging from a

minimum level to a maximum level of scene components that

can be included in the corrected-sensitivity picture data

MDOALLi. For example, the value ranges from MOUT/M to

MOUT x (M + 1)/M where notation M denotes the maximum

computation count. The tentative constant Ihj can have a

value ranging from a minimum level to a maximum level of

house shading components that can be included in the

corrected-sensitivity picture data MDOALLi. For example,

the value ranges from MOUT/M to MOUT x (M + 1)/M. Then, values of ISk and Ihj are computed for j and k that minimize the squared error SE (j, k) where notations j, k, j and k each denote a computation count. The value of Ihj becomes housing component intensity Ih where SE is minimized.

(b-2) Housing shading correction quantity computing

The housing-shading-correction-quantity-computing unit 60 multiplies the housing component intensity Ih by the housing response profile PROFi stored in the housing-response-profile storage memory 56 for all detector elements i of the infrared sensor 16 to output a housing shading correction quantity MDHSi (= PROFi x Ih).

(b-3) Housing shading correction

The housing-shading-correction-processing unit 62 subtracts the housing shading correction quantity MDHSi from the corrected-sensitivity picture data MDOALLi to compute housing-shading-corrected picture data OUTi (= MDOALLi - MDHSi). As shown in FIG. 21, in the case of a uniform scene, the housing-shading-corrected picture data OUTi consists of only a uniform-scene components MDSNi and is uniform independently of the detector element i. In addition, even in the case of a non-uniform scene including a partially uniform portion, the least-square

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method can be applied to correct shading components caused by the housing. Thus, the housing-shading-corrected picture data OUTi consists of only uniform-scene components MDSNi shown in FIG. 22 as a result of the housing-shading correction. An example of the non-uniform scene including a partially uniform portion is a scene detected by detector elements at locations in close proximity to the right edge of corrected-sensitivity picture data shown in FIG. 22. In the case of a non-uniform scene including no partially uniform portion, on the other hand, the least-square method cannot be applied. Thus, the housing shading correction cannot be carried out. Since Ihk becomes approximately 0, however, the housing shading correction quantity also becomes approximately 0. As a result, there will be no picture-quality deterioration due to the fact that the picture data OUTi output by the housing-shading-correction-processing unit 62 is subjected to the housing shading correction unconditionally.

(c) Image processing

The image-processing unit 44 inputs the picture data OUTi, which has completed correction of shading components caused by the optical system and correction of shading components caused by the housing, carries out

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image processing on the input picture data OUTi and

displays the data OUTi for each detector element i. At

that time, since the picture data OUTi has completed

correction of shading components caused by the optical

system and correction of shading components caused by the

housing, the quality of the image processing can be

improved. In the case of an infrared imaging apparatus

mounted on a missile seeker, for example, it is possible

to keep track of a target with a higher degree of

reliability.

Second Embodiment

FIG. 23 is a diagram showing the configuration of

an infrared imaging apparatus implemented by a second

embodiment of the present invention. Configuration

elements of the second embodiment, that are essentially

identical with those employed in the first embodiment

shown in FIG. 2, are denoted by the same reference

numerals as the latter. A scanning unit 150 is a unit for

driving the camera head 2 so as to move the view axis of

the camera head 2 in a scanning movement. The view axis

is an optical path of infrared rays passing through the

center of the lens 8. In the case of a scene including no

partially uniform portion, the view axis is put in a

scanning movement and picture data obtained as a result

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of the scanning operation is smoothed to produce a partially uniform scene which can be subjected to housing shading correction.

FIG. 24A is an explanatory diagram used for describing view axis scanning in the vertical direction. On the other hand, FIG. 24B is a diagram showing view axis scanning in the horizontal direction. As shown in FIG. 24A, by rotating the camera head 2 in the up and down directions with a horizontally oriented axis 162 taken as the center of rotation, a view axis 160 scans a range 168 between arrows 164 and 166 in the vertical direction. As shown in FIG. 24B, by rotating the camera head 2 in the horizontal direction with an axis 171 taken as the center of rotation, a view axis 160 scans a range 176 between arrows 172 and 174 in the horizontal direction. The axis 171 is set vertically in a direction normal to the axis 162. The scanning unit 150 drives the view axis 160 in a scanning movement by periodically moving the view axis 160 in the horizontal and vertical directions over a fixed range. The view axis scanning is carried out merely to obtain a partially uniform scene. For example, the periodical scanning movement is carried out at a frequency of 1 Hz to form a circular scanning range with a scanning radius equivalent to that of the

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field of view of the image-taking unit.

FIG. 25 is a diagram showing a typical configuration of the scanning unit 150 employed in the infrared imaging apparatus. The figure shows a horizontal cross section which is obtained for a case in which the infrared imaging apparatus is mounted on a missile seeker. As shown in FIG. 25, the camera head 2 is accommodated in a dome 180 made of an infrared-transparent material and used for protecting the camera head 2. The camera head 2 is driven into a vertical-direction scanning movement centered at an axis 162 on a gimbal 150 in a horizontal direction to put the view axis 160 in a vertical-direction scanning movement. Much like the axis 162 shown in FIG. 25, another axis is put on the gimbal 150, being oriented in a vertical direction. The camera head 2 is driven into a horizontal-direction scanning movement centered at the other axis to put the view axis 160 in a horizontal-direction scanning movement.

FIG. 26 is a diagram showing the configuration of the shading-correction unit 152 employed in the infrared imaging apparatus shown in FIG. 23. Configuration elements of the shading-correction unit 152 shown in FIG. 26, that are essentially identical with those employed in the shading-correction unit 42 shown in FIG. 3, are

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denoted by the same reference numerals as the latter. As shown in FIG. 26, the shading-correction unit 152 has a smoothing-process unit 190 in addition to the configuration elements employed in the shading-correction unit 42. The shading-correction unit 152 is different from the shading-correction unit 42 shown in FIG. 3 in that, in the case of the shading-correction unit 152, the housing-component-intensity-processing unit 192 computes the intensity of a housing component not for corrected-intensity picture data output by the sensitivity-correction-processing unit 52, but for picture data output by the smoothing-process unit 190.

The smoothing-process unit 190 computes integrated picture data by integration of corrected-sensitivity picture data with respect to detector elements i over a predetermined number of frames and computes averaged picture data from the integrated picture data, supplying the averaged picture data to the housing-component-intensity-processing unit 58. Since the picture data is obtained as a result of a scanning operation by scanning a view axis, the integrated and averaged picture data obtained as a result of a smoothing operation for detector elements i becomes an average value of pieces of picture data in the scanning range of

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the view axis. This processing is thus equivalent to an operation to find an average and uniform value of scene components incident to the detector elements i, making it possible to obtain picture data of a locally uniform scene. The smoothing operation is carried out for typically frames appearing in a time equal to the period of the view axis scanning. If the period of the view axis scanning is 1 second for a frame frequency of 100 Hz, 100 frames appear during the period of 1 second, for example, the smoothing operation is integration of picture data over a period of 1 second and division of the integration result by the number of frames appearing during the period. If the number of frames to be smoothed is a power of 2, the division can be implemented by a bit-shift operation which is simple processing. The integrated and averaged data is updated each smoothing time.

FIG. 27 is a diagram showing the smoothing-process unit 190 employed in the shading-correction unit 152 shown in FIG. 26. As shown in FIG. 27, the smoothing-process unit 190 comprises an adder 200, a RAM 202, a selector 204, a shifter 206 and an integration-count control unit 208. The adder 200 cumulatively adds or integrates corrected-sensitivity picture data MDOALLi output by the sensitivity-correction-processing unit 52

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for each detector element i to data output by the

selector 204 and outputs the sum to the RAM 202. The RAM

202 is a memory for storing picture data obtained as a

result of integration of pieces of corrected-sensitivity

picture data MDOALLi with respect to the detector element

i over a plurality of frames. The selector 204 supplies

integrated picture data to either the adder 200 or the

shifter 206 in dependence on a select signal output by

the integration-count control unit 208. The shifter 206

carries out a bit-shift operation on the integrated

picture data received from the selector 204 in accordance

with a command issued by the integration-count control

unit 208 in order to divide the level of the picture data

by a power of 2. The shifter 206 outputs integrated and

averaged picture data as a result of the bit-shift

operation. The integration-count control unit 208 carries

out the following operations synchronously with frames of

corrected-sensitivity picture data and with outputs of

each detector element:

1: Clear data stored in the RAM 202 for each

predetermined number of frames.

2: Output a read address for corrected-sensitivity

picture data MDOALLi input by the adder 200 for each

detector element i to the RAM 202 for use by the selector

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204 to read integrated data from the RAM 202.

3: Output a write address for corrected-sensitivity picture data MDOALLi input by the adder 200 for each detector element i to the RAM 202 for use by the adder 200 to write a sum into the RAM 202.

4: Output a select signal to the selector 204 to output integrated picture data to the adder 200 during a period of integration or to output integrated picture data to the shifter 206 at the end of a period of integration.

5: Output a control signal indicating that integrated and averaged picture data is being output to the housing-component-intensity-processing unit 192.

It should be noted that, also as an embodiment of the present invention, there is provided a smoothing method for repeatedly carrying out an operation to integrate pieces of picture data over a predetermined plurality of frames and to take an average of integration results. Other methods include the so-called moving-averaging technique or the so-called exponential-smoothing technique. It is needless to say that any method can be adopted as long as the method is capable of smoothing picture data along the time axis for each detector element.

The housing-component-intensity-processing unit 192

computes a housing-component intensity Ih from integrated
and averaged picture data for predetermined detector
elements i synchronously with a control signal generated
by the smoothing-process unit 190 to indicate that the
integrated and averaged picture data output by the
smoothing-process unit 190 is available. The housing-
component-intensity-processing unit 192 then outputs the
housing-component intensity Ih to the housing-shading-
correction-quantity-computing unit 60.

The operation of the infrared imaging apparatus
shown in FIG. 23 is described as follows.

Sensibility-correction calibration data and housing
response profiles are created in the same way as the
first embodiment.

(a) Scanning field of view

The infrared imaging apparatus applied to a variety of
fields including a missile seeker puts the view axis of
the camera head 2 in a scanning movement at a fixed
period by using the scanning unit 150 such as a gimbal.
At a frequency of about 1 Hz, for example, the view axis
is put in a scanning movement along a circular locus with
a scanning radius equivalent to that of the field of view
of the infrared imaging apparatus. It should be noted
that, in a missile seeker, a gimbal serving as the

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scanning unit 150 is provided for orienting the view axis
in the target direction or driving the view axis to track
the target. It is possible to carry out the operation to
drive the view axis in a scanning movement for obtaining
a locally uniform scene continuously or intermittently in
parallel to operations to search for a target and to
follow up the target or other operations. As long as
shading components caused by the housing do not vary due
to changes in temperature of the camera head 2, because
it is not necessary to compute shading components caused
by the housing, there is no problem with the time of view
axis scanning even if the view axis scanning is carried
out intermittently. Picture data obtained as a result of
a scanning operation carried out by the scanning unit 150
using the view axis of the camera head 2 is converted by
the AD converter 40 into digital picture data which is
then supplied to the sensitivity-correction-processing
unit 52.

(b) Sensitivity correction

Much like the first embodiment, the sensitivity-
correction-processing unit 52 carries out sensitivity
correction on the digital picture data, outputting
corrected-sensitivity picture data for each detector
element i to the smoothing-process unit 190 and the

housing-shading-correction-processing unit 62.

(c) Smoothing process

The smoothing-process unit 190 integrates the signals every the detector element i outputted by the elements over a predetermined number of frames before an averaging process by bit-shifting of a result of integration. The smoothing-process unit 190 then outputs the integrated and averaged picture data to the housing-component-intensity-processing unit 192. The smoothing-process unit 190 also supplies a control signal to the housing-component-intensity-processing unit 192 to indicate that the integrated and averaged picture data is available. Since the input picture data is obtained as a result of a scanning operation using a view axis, the integrated and averaged picture data with respect to detector elements is equivalent to a locally uniform scene.

(d) Housing component intensity processing

The housing-component-intensity-processing unit 192 computes a housing-component intensity Ih from integrated and averaged picture data for predetermined detector elements i synchronously with a control signal generated by the smoothing-process unit 190 to indicate that the integrated and averaged picture data output by the

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smoothing-process unit 190 is available in the same way
as the first embodiment. The housing-component-intensity-
processing unit 192 then outputs the housing-component
intensity Ih to the housing-shading-correction-quantity-
computing unit 60. Since the integrated and averaged
picture data represents a locally uniform scene, the
housing-component intensity Ih can be computed with a
high degree of accuracy in comparison with the first
embodiment.

(e) Housing shading correction quantity computing

The housing-shading-correction-quantity-computing
unit 60 multiplies the housing response profile PROFi by
the housing-component intensity Ih for each detector
element i to compute a housing shading correction
quantity. The housing response profile PROFi is stored in
the housing-response-profile storage memory 56 for all
detector elements i of the infrared sensor 16. The
housing-shading-correction-quantity-computing unit 60
supplies the housing shading correction quantity to the
housing-shading-correction-processing unit 62.

(f) Housing shading correction

The housing-shading-correction-processing unit 62
subtracts the housing shading correction quantity from
the corrected-intensity picture data for each detector

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element i and outputs the difference resulting from the
subtraction to the image-processing unit 44.

(g) Image processing

The image-processing unit 44 receives picture data
completing correction of shading components caused by the
optical system and correction of shading components
caused by the housing in the shading-correction unit 152,
carrying out image processing on the received picture
data. The image-processing unit 44 then displays results
of the image processing on a display unit or the like. At
that time, the image data is performed the same
correction of shading components caused by the optical
system as the first embodiment and more accurate
correction of shading components caused by the housing
than the first embodiment. As a result, the picture
quality is improved better than the first embodiment.

Third Embodiment

FIG. 28 is a diagram showing the configuration of
an infrared imaging apparatus implemented by a third
embodiment of the present invention. Configuration
elements of the third embodiment, that are essentially
identical with those employed in the second embodiment
shown in FIG. 23, are denoted by the same reference
numerals as the latter. The correction of variations in

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characteristics of detector elements by the sensitivity-correction-processing unit 56 in the first and second embodiments is generally correction of variations in basic characteristic that are not accompanied by a change in characteristic-variation with the lapse of time. In the case of the third embodiment, on the other hand, a shading-correction unit 210 corrects variations in characteristic with a time lapse, which change in the course of operation, by carrying out offset correction.

FIG. 29 is a diagram showing the configuration of the shading-correction unit 210 employed in the infrared imaging apparatus shown in FIG. 28. Configuration elements of the shading-correction unit 210, that are essentially identical with those employed in the shading-correction unit 152 shown in FIG. 26, are denoted by the same reference numerals as the latter. A local-correction-data-creating unit 220 carries out the following pieces of processing on integrated and averaged picture data generated by the smoothing-process unit 190 for detector elements i:

1: Compute an average value for devices surrounding a detector element i.

2: Subtract the picture-data level of a detector element i from the average value for surrounding devices and

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output the difference resulting from the subtraction to an offset-correcting unit 222 as an offset calibration value for the detector element i.

A locally uniform scene can be obtained from the smoothing-process unit 190. Thus, variations in characteristic, which are caused with the lapse of time, are corrected by using the offset calibration value because the difference between the average value of surrounding devices and the detector element i of interest is regarded as characteristic variations caused by the lapse of time.

FIG. 30 is a diagram showing the configuration of the local-correction-data-creating unit 220 employed in the shading-correction unit 210 shown in FIG. 29. As shown in FIG. 30, the local-correction-data-creating unit 220 comprises a local-area-average-value-processing unit 230, a RAM 232 and an adder 234. The local-area-average-value-processing unit 230 computes an average value for devices surrounding a detector element i. Such an average value is also referred to hereafter as a local-area average value. Detector elements surrounding a particular detector element are located in a local area with the particular detector element serving as the center of the area. For example, the local area has dimensions of 11

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elements X 11 elements. The RAM 232 is a memory for
storing integrated and averaged picture data of all
detector elements i. The adder 234 reads an integrated
and averaged picture data of all detector elements i from
the RAM 232, and subtracts the integrated and averaged
picture data of all detector elements i from an average
value for devices surrounding a particular detector
element i to output a correction calibration quantity for
the particular detector element i. The integrated and
averaged picture data is to be subtracted from the
average value as described above.

FIG. 31 is a diagram showing the configuration of
an offset-correction unit 222 employed in the shading-
correction unit shown in FIG. 29. As shown in FIG. 31,
the offset-correction unit 222 has an adder 240. The
adder 240 adds corrected-sensitivity picture data of a
detector element i to correction calibration data for the
detector element i in order to correct characteristic
variations caused by the lapse of time.

The operation of the infrared imaging apparatus
shown in FIG. 28 is described as follows.

Sensibility-correction calibration data and housing
response profiles are created in the same way as the
first embodiment.

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(a) Scanning field of view

Much like the second embodiment, the infrared imaging
apparatus puts the view axis of the camera head 2 in a
scanning movement at a fixed period by using the scanning
unit 150 such as a gimbal. Picture data obtained as a
result of a scanning operation carried out by the
scanning unit 150 using the view axis of the camera head
2 is converted by the AD converter 40 into digital
picture data which is then supplied to the sensitivity-
correction-processing unit 52.

(b) Sensitivity correction

Much like the first embodiment, the sensitivity-
correction-processing unit 52 carries out sensitivity
correction on the digital picture data, outputting
corrected-sensitivity picture data for each detector
element i to the smoothing-process unit 190 and the
housing-shading-correction-processing unit 62.

(c) Smoothing

Much like the second embodiment, after the smoothing-
process unit 190 integrates the corrected-sensitivity
picture data with respect to the detector element i over
a predetermined number of frames, it performs an
averaging process by bit-shifting of a result of
integration. The smoothing-process unit 190 then outputs

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the integrated and averaged picture data to the housing-component-intensity-processing unit 192 and the local-correction-data-creating unit 220.

(d) Local correction data creating

The local-correction-data-creating unit 220 computes a local-area average value for detector elements i. For each detector element i, the local-correction-data-creating unit 220 calculates a correction calibration quantity by using the local-area average value for detector elements i.

(e) Local correction data creating

The C unit 222 adds corrected-sensitivity picture data for each detector element i to the correction calibration quantity of the detector element i to correct variations in characteristic of the corrected-sensitivity picture data, which are caused by the lapse of time.

(f) Housing component intensity processing

Much like the second embodiment, the housing-component-intensity-processing unit 192 computes a housing-component intensity Ih from integrated and averaged picture data for detector elements in a predetermined area, and outputs the computed housing-component intensity Ih to the housing-shading-correction-quantity-computing unit 60. It should be noted that, instead of

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supplying integrated and averaged data obtained as a
result of integration and averaging by the smoothing-
process unit 190 to the housing-component-intensity-
processing unit 192, picture data completing offset
correction in the offset-correction unit 222 can also be
subjected to the same integration and averaging as the
processes carried out by the smoothing-process unit 190
to produce integrated and averaged picture data.

(g) Housing shading correction quantity computing

The housing-shading-correction-quantity-computing
unit 60 multiplies the housing response profile PROFi by
the housing-component intensity Ih for each detector
element i to compute a housing shading correction
quantity. The housing response profile PROFi is stored in
the housing-response-profile storage memory 56 for all
detector elements i of the infrared sensor 16. The
housing-shading-correction-quantity-computing unit 60
supplies the housing shading correction quantity to the
housing-shading-correction-processing unit 62.

(h) Housing shading correction processing

The housing-shading-correction-processing unit 62
subtracts the housing shading correction quantity from
the corrected-offset picture data for each detector
element i, and outputs the difference resulting from the

subtraction to the image-processing unit 44.

(i) Image processing

The image-processing unit 44 receives picture data completing correction of shading components caused by the optical system, correction characteristic variations caused by the lapse of time and correction of shading components caused by the housing in the shading-correction unit 210, carrying out image processing on the received picture data. The image-processing unit 44 then displays results of the image processing on a display unit or the like. At that time, the picture data has completed the correction of shading components caused by the optical system, the correction characteristic variations caused by the lapse of time and the correction of shading components caused by the housing. As a result, the picture quality is further improved.

In accordance with the present invention, since shading components caused by the optical system and shading components caused by the housing are corrected, the picture quality is improved.

The present invention is not limited to the details of the preferred embodiments described above. The scope of the present invention is defined by appended claims and all changes and modifications as fall within the

equivalence of the scope of the claims are therefore to

be embraced by the invention.